date and do not give enough specific applications to the Earth Sciences. Of the 59 works cited in either ‘references’ or ‘further reading’, 25 per cent are to entries in the 1984 *Encyclopaedia Britannica* and only 15 per cent concern works published after 1980. Some of the older references are key ones, but this should not lead to exclusion of more recent Earth Science references to enthuse students who have gained from other parts of the text. For instance, how can the last few pages on linear regression fail to point the student to the excellent text by Davis (1986), which goes into far more depth on this topic? Annoyingly, some of the equations are numbered whilst others are not (which will make tutorial use of the book more difficult), and some things are plainly wrong. For instance, p. 103 discusses the laminar/turbulent transition by stating that the smooth upper surface of a stream shows laminar behaviour until the stream narrows and becomes rough water, this error being especially inappropriate since it follows closely a paragraph that laments a literature full of careless errors on the subject of fluid flow.

Lastly, for use as an ancillary course text I would have liked to see more problems and examples, with workings and solutions, after each chapter. This would have both addressed the above point of Earth Science relevance and provided a more readily usable text as either part of a course or in tutorials. Given the competition that this book faces, in part, for instance, from the excellent *Mechanics in the Earth and Environmental Sciences* by Middleton and Wilcock (which does provide problems), the inclusion of these examples seems a serious omission.

However, even given its shortcomings and the obvious requirements for any second edition, a copy of this book should reside on library shelves and will be very well used. In places, it acts more like a dictionary, but it makes basic principles accessible to those who may need to renew their background in these fundamentals of physics, but have not yet found an accessible source.

REFERENCE

Davis, J. C. 1986. *Statistics and Data Analysis in Geology,* John Wiley & Sons, New York, 646 pp.

JIM BEST
University of Leeds, UK

SPACE AND TIME VARIABILITY AND INTER-DEPENDENCIES IN HYDROLOGICAL PROCESSES edited by Reinder A. Feddes, Cambridge University Press, Cambridge, 1995. No. of pages: xii + 181. Price: £55.00 (hb). ISBN 0-521-49508-3.

Scale problems are a hot topic for meetings in hydrology. This volume arises from the first George Kovacs colloquium of the International Hydrology Program/International Association of Hydrological Sciences, held in Paris in July 1992. The proceedings of another workshop, on ‘Scale Issues in Hydrological Modelling’ in Robertson, Australia, in December 1993 have also just been published by John Wiley & Son Ltd (edited by Jetse Kalma and Murugesu Sivipalan). There will be further workshops in 1996 in Vienna and Wallingford, and the study of scale problems in time and space is intrinsic to programmes such as BOREAS, GEWEX, GCIP and the NERC TIGER and LOIS programmes. The major problems being addressed are:

(i) what are the constraints on the change in hydrological behaviour in moving from one scale to another, given the time and space variability apparent in hydrological responses?
(ii) how far are such constraints evident in field data?
(iii) can a theory of scaling be developed to reflect such constraints, such that observations at one scale can be used to infer behaviour at another? and
(iv) what are the implications of scale-dependent behaviour for modelling global change, in both upscaling small-scale heterogeneity to the grid scale of global models, and downscaling grid-scale predictions for use at smaller scales?

All these problems are apparent in the papers in this volume, which generally maintain a high standard of presentation in combining review material with new research. After the opening address of the colloquium by Shamir, the papers may be broadly grouped into three sets. First, there is a set of papers that concentrate on scale problems in hydrological responses. These include papers by Wood on ‘Hetereogeneity and scaling land-atmospheric water and energy fluxes in climate systems’, Dooge on ‘Scale problems in surface fluxes’, Feddes on ‘Remote sensing-inverse modelling approach to determine large scale effective soil hydraulic properties’, Hatton *et al.* on ‘The importance of landscape position in scaling SVAT models to catchment scale hydroecological prediction’, Becker on ‘Problems and progress in macroscale hydrological modelling’, and Nachtnebel on ‘Dependencies of spatial variability in fluvial ecosystems on the temporal hydrological variability’.

There is then a set of papers dealing more specifically with the interaction of atmospheric models with land surface hydrology, including Entekhabi on ‘The influence of subgrid-scale spatial variability on precipitation and soil moisture in an atmospheric GCM’, Henderson-Sellers *et al.* on ‘Modelling the hydrological response to large scale land use change’, Avissar and Chen on ‘Subgrid-scale fluxes in GCMs demonstrated with simulations of local deforestation in Amazonia’, Kite *et al.* on ‘A hierarchical approach to the connection of global hydrological and atmospheric models’, and Bardossy on ‘Stochastic downscaling of GCM-output results using atmospheric circulation patterns’. The final group of papers is concerned with the use of fractals as a description of scaling behaviour and include Nicolis on ‘Predictability of the atmosphere and climate: towards a dynamical view’, Shertzer and Lovejoy on ‘From scalar cascades to lie cascades: joint multifractal analysis of rain

and cloud processes', and Hubert on 'Fractals et multifractals appliqués à l'étude de la variablité temporelle des précipitations'.

Study of scaling in hydrology has been constrained by availability of spatial data sets, of measurement techniques to observe responses at certain scales, and of computer time. Because of the lack of direct measurement techniques, many studies are based on numerical experimentation, with all its limitations. This shows that for both surface and subsurface hydrological responses (e.g. Wood, Hatton *et al*.) and for surface–atmosphere interactions (e.g. Avissar and Chen), the use of grid-scale effective parameters to represent large-scale fluxes is not adequate. Non-linear variability within mesoscale circulations and hydrological fluxes is important, and new ways must be found to parameterize scale fluxes to reflect such variability. The difficulty is that the observational data do not exist to allow this – we do not even know what the answer is at the GCM grid scale, and have not observed the subgrid-scale processes that might allow such a parameterization to be developed. One hope, of course, is in the spatial coverage provided by remote sensing. In the past this has not been very useful in the study of land surface processes. Images have been used for classification of the surface but not much more. The paper by Feddes suggests that by combining remote sensing with theory (and some necessary but arguable assumptions) it may be possible to go further than this and at least make an assessment of the variability in the energy budget components within a region. The histograms presented illustrate the limitations of using the type of lumped effective parameters currently employed at the grid scale in most current GCMs (although see the paper by Entekhabi for an example of including some subgrid-scale variability). Feddes concludes that small-scale physics can adequately describe large-scale hydrological variability by using a multiple column approach, where the parameters for the columns are derived by inverse modelling against local data. It would be interesting to see how well this conclusion holds in other areas and in extrapolating to other conditions. Such inverse solutions tend to be fraught with uncertainty.

This type of tiling (or statistical dynamical) approach to scaling is the nearest thing available to a scaling theory in hydrological–atmospheric interactions. The search for something more sophisticated includes the fractal and multifractal approaches covered in the papers by Nicolis, Schertzer and Lovejoy, and Hubert. The links to non-linear dynamics are suggested by Nicolis, and Schertzer and Lovejoy, and seem to hold some promise for the study of atmospheric dynamics and for the results of those interactions as seen in rainfalls at the ground surface (Hubert). Fractal descriptions of the landscape, river networks and soil characteristics have also been dealt with elsewhere, but linking these descriptions back to process dynamics still seems a long way off.

Uncertainty does not appear very much in this volume (but see the volume edited by Kundzewicz (1995) in the same series). It appears that in the numerical study of scaling problems, computer limitations are already constraining enough without having to include the effects of uncertainty as well. Yet, ultimately, there will be much uncertainty about scaling.

KEITH BEVEN
Lancaster University, UK